White Paper

Color Matching Between sRGB Monitors and Wide Color Gamut Monitors

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1. Introduction

Eizo Nanao Corporation has sold the ColorEdge series of color management monitors since May 2003. These monitors are widely used in graphics, printing, and photographic markets.

The color gamut of input and output devices has grown significantly wider in recent years, as evidenced by the advent of Adobe RGB supported monitors, digital cameras, and printing inks. This has led to the spread of the Adobe RGB workflow. In December 2004, we developed and launched our first color management monitor (ColorEdge CG220) that reproduces the Adobe RGB color gamut. Since that time we have released several other wide color gamut monitors.

Recently, we occasionally encounter cases in which the colors displayed on images are different between a conventional color gamut sRGB monitor and a wide color gamut monitor like those mentioned above.

This white paper discusses various issues that arise with visual color matching between sRGB monitors and wide color gamut monitors. It also discusses countermeasures incorporated into monitors and calibration software.

2. sRGB Monitors and Wide Color Gamut Monitors

2-1. Differences in color gamut between sRGB and wide color gamut monitors

Table 1 lists the EIZO ColorEdge series monitors compatible with wide color gamuts and their Adobe RGB coverage* (as of April 2008). Comparisons of sRGB and Adobe RGB (a typical wide color gamut standard) shows that the Adobe RGB color gamut is wider than the sRGB color gamut in the green region (see Table 2 and Table 3). This allows the wide color gamut monitor to achieve more accurate expression of not just greens, but colors high in chroma saturation, like cyan, yellow, and orange, which cannot be expressed in the sRGB color gamut (see Fig. 1).

**The Adobe RGB coverage indicates the percentage of the Adobe RGB color gamut covered by the monitor.*

Monitor	Adobe RGB coverage
CG221	98%
CG241W	96%
CG222W	92%

Table 1: Wide color gamut monitors and their Adobe RGB coverage

	X	y
R	0.640	0.330
G	0.210	0.710
B	0.150	0.060

Table 2: Adobe RGB color coordinates

	x	Y
R	0.640	0.330
G	0.300	0.600
B	0.150	0.060

Table 3: sRGB color coordinates

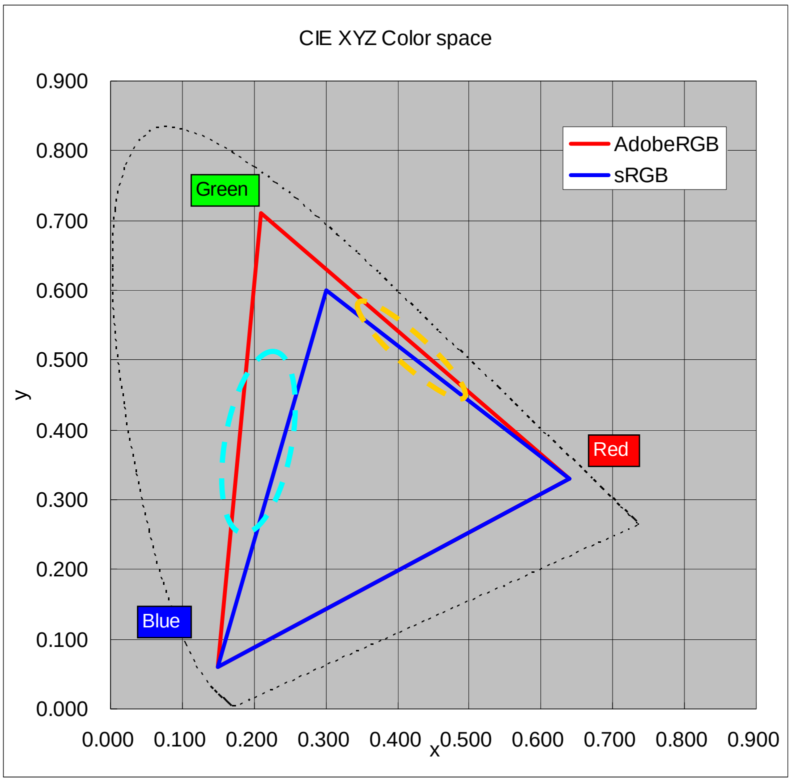


Figure 1: Color gamut comparison between sRGB and Adobe RGB

2-2. Visual difference between sRGB and wide color gamut monitors

Next, we will examine an sRGB monitor and a wide color gamut monitor, both calibrated based on the same target values. If we compare two sRGB monitors, the color displayed by the two monitors looks the same. Below we will examine the colors displayed by a sRGB monitor and a wide color gamut monitor.

Fig. 2 shows an sRGB monitor on the left (CG211) and a wide color gamut monitor (CG241W) on the right. Both monitors are calibrated and set to the same target values (brightness: 100 cd/m^2, color temperature: 5000 K, gamma value: 2.2, measurement device: Eye-One Pro) and are displaying a white screen. This comparison clearly shows that the color differs between the two monitors with the sRGB monitor having a bluish color, despite calibration with the same target values. What causes this difference?

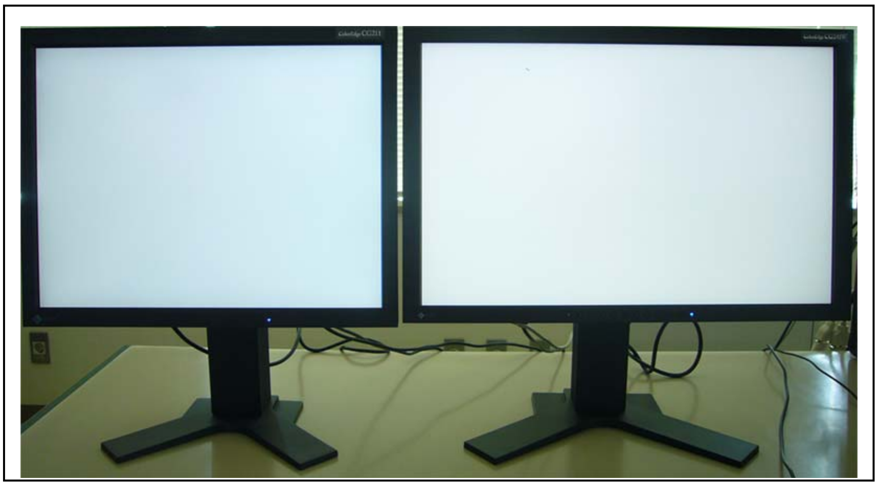


Figure 2: Comparison of monitors with different color gamuts

3. Color evaluation differences between a measurement device and visual evaluation

Here we analyze why the white screens displayed by sRGB and wide color gamut monitors appear differently, even when calibrated with the same target values as described in the previous section (2.2).

3-1. Actual measurements

Fig. 3 shows measurements taken with the white screens displayed by the CG211 (sRGB) and CG241W (wide color gamut) (see Fig. 2 in Section 2.2) with a measuring instrument (2-degree field of view, XYZ color space). In this measurement example, measurements taken with the CG211 and CG241W are practically identical.

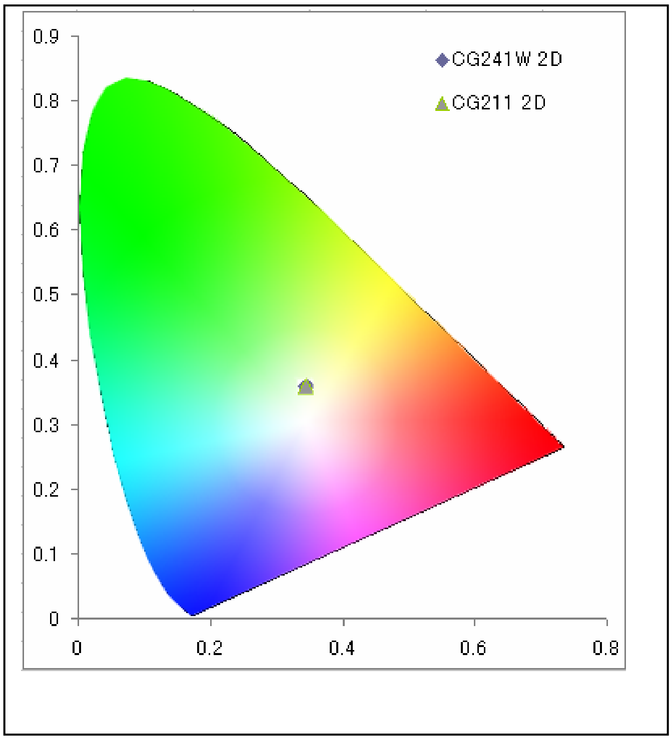


Figure 3: Deviation between subjective visual assessment and instrument measurements

3-2. Measuring the color displayed on a monitor (with a measuring device)

The following method is used to measure colors on a monitor.

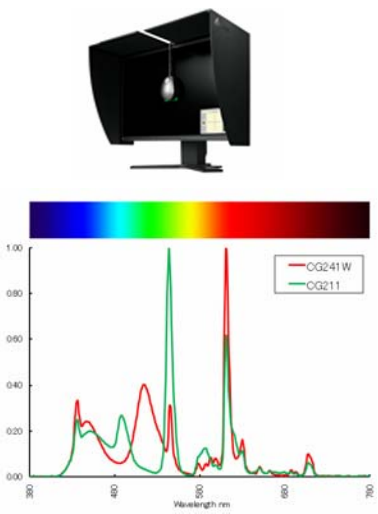
(1) The spectral distribution characteristics of the monitor and the measurement sensitivity (RGB) of the measuring devices are multiplied (XYZ value).

(2) The XYZ value obtained by the above calculation is used to calculate the color coordinates.

Fig. 4 shows the spectral distribution characteristics of the CG211 and CG241W. It shows a significant difference between an sRGB monitor and a wide color gamut monitor in waveform characteristics near wavelengths (450 to 550 nm) corresponding to green.

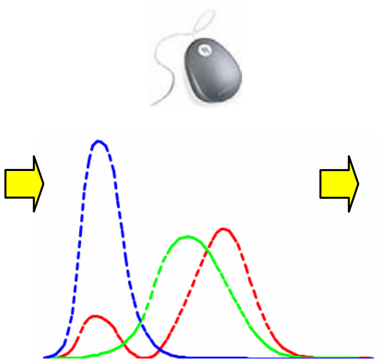
However, since the color indicated by the measurement corresponds to the superimposition of the spectral distribution characteristic of the monitor and the sensitivity (RGB) of the measuring device, as described above in (1), the measurement (XYZ values in red) will be the same in certain cases, even if the shapes of the overlapping sections (daubed sections in the rightmost figures below) differ.

Since the obtained measurement (XYZ values in red) is the same for the CG241W and CG211, the colors displayed by the two monitors are considered as the "same color" in terms of instrument measurements.



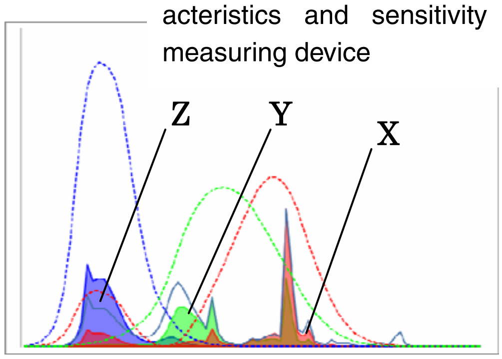
Spectral distribution of monitor

Measurement with instrument



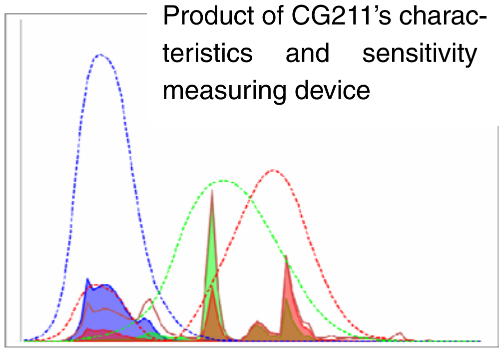
Sensitivity of measuring device

Product of CG241W's characteristics and sensitivity of measuring device



	X	Y	Z
CG241W	115	120	113

Product of CG211's characteristics and sensitivity of measuring device



	X	Y	Z
CG211	115	120	113

Figure 4: Product of spectral distribution characteristics of CG211/CG241W and measurement sensitivity of measuring device

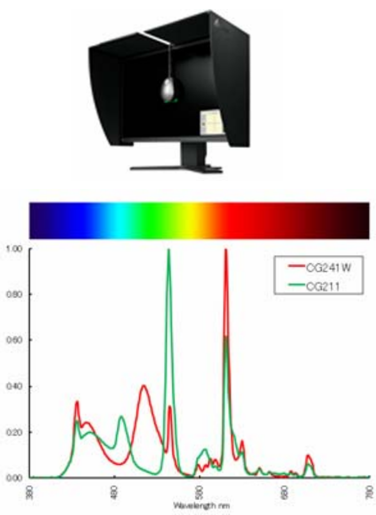
3-3. Measuring the color displayed on a monitor (with visual evaluation)

The following method is used to “measure” colors on a monitor based on visual evaluation.

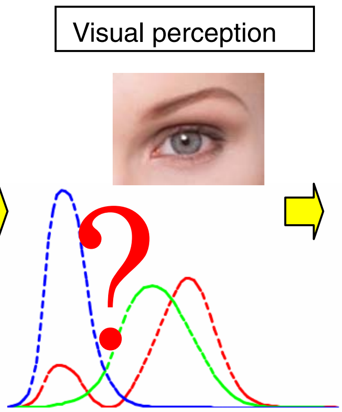
(1) The spectral distribution characteristics of the monitor and the visual sensitivity (RGB: technically they are called LMS cones) of the eyes are multiplied (superimposed).

(2) The RGB (LMS) obtained by the above calculation is used to evaluate colors.

Although the “calculation” described above is more accurately an “interpretation” than an arithmetical process, the principles of measurement are the same as with a measuring device. Here, the measurement is a value obtained by superimposing the spectral distribution characteristics of the monitor and the sensitivity of the human eye. If measurements with the measuring device differ from those based on visual evaluation (i.e., when A, B, and C differ from A’, B’, and C’), we conclude that the sensitivity of the measuring device may differ from the sensitivity of the human eyes.

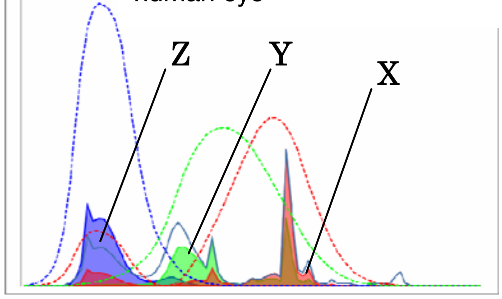


Spectral distribution of monitor



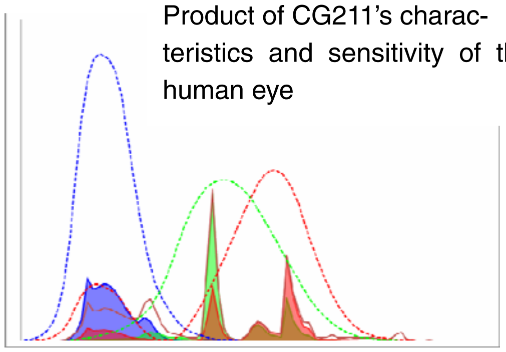
Sensitivity of the human eye

Product of CG241W’s characteristics and sensitivity of the human eye



	X	Y	Z
CG241W	A	B	C

Product of CG211’s characteristics and sensitivity of the human eye



	X	Y	Z
CG211	A’	B’	C’

Figure 5: Product of spectral distribution characteristics of CG211/CG241W and sensitivity of the human eye

4. Color matching based on measurement device and visual evaluation

Discussed below are color-matching methods based on measurement device and visual evaluation.

4-1. XYZ color space based on a 2-degree field of view and a 10-degree field of view

The commonly used color management rules stipulate the use of the XYZ color space based on a 2-degree field of view (also called $X_2Y_2Z_2$ color space) for device measurements. Needless to say, the XYZ color space based on a 2-degree field of view is also used to calibrate monitors and in the production of color profiles.

The basis of the XYZ color space is based on the color matching experiment of 2-degree field of view. The "2 degrees" in "2-degree field of view" refers to the field of view from the observer's eye across which the observer examines the object, as illustrated in Fig. 6. However, experiments conducted later showed that spectral sensitivity varied, depending on the width of the image falling on the retina of the observer's eye. In response, the CIE (International Commission on Illumination) in 1964 established an additional color space based on a 10-degree field of view ($X_{10}Y_{10}Z_{10}$ color space). However, the XYZ color space based on a 2-degree field of view has become a *de facto* standard for color management.

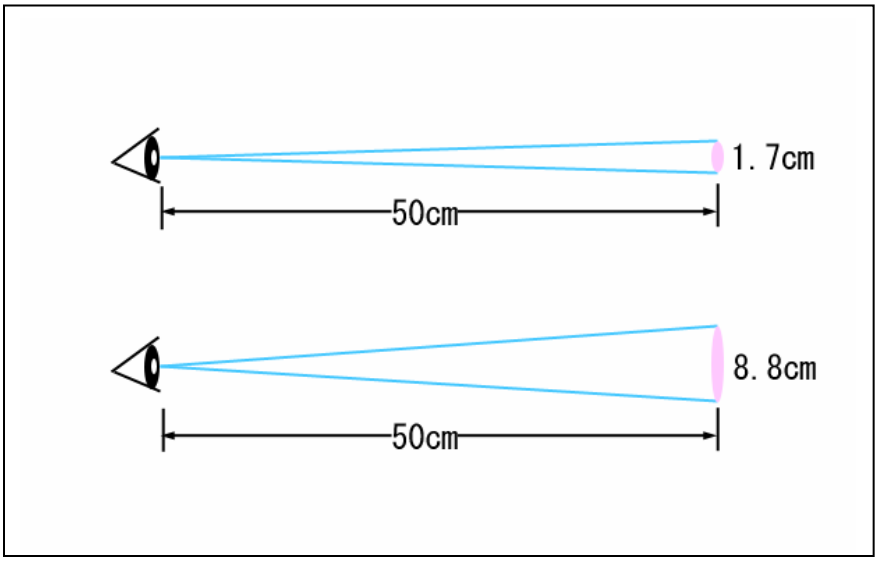


Figure 6: 2-degree and 10-degree fields of view

4-2. Actual field of observation view of monitors

In many cases, in actual work performed with monitors, whole screens are observed and compared, as shown in Fig. 7. For this reason, we believe the actual conditions of observation for monitor color matching are closer to the conditions of the 10-degree field of view than to those of the 2-degree field of view.

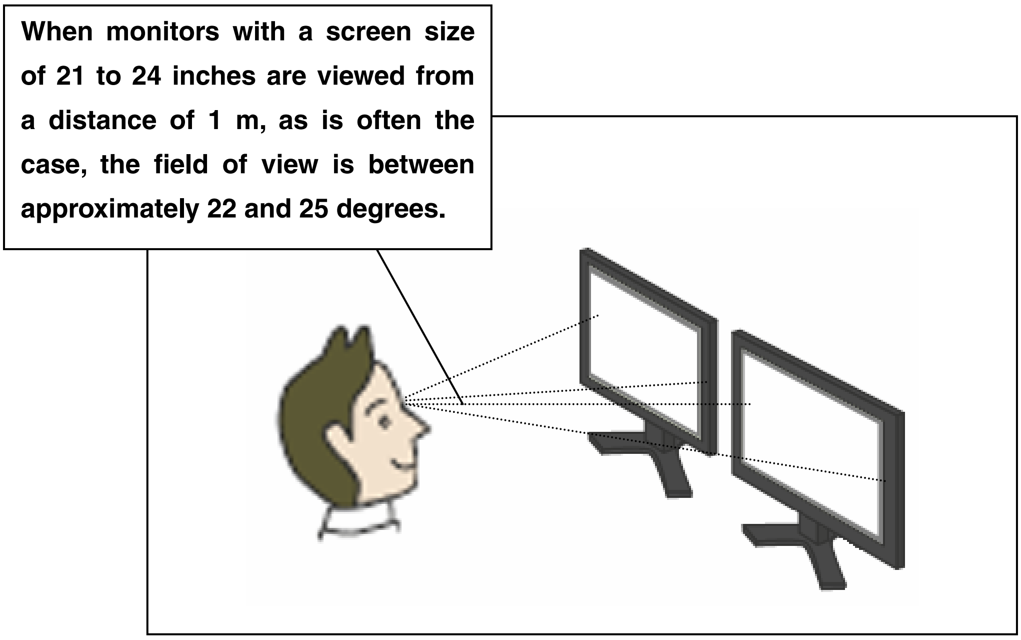


Figure 7: Field of view during actual monitor use

4-3. Calibration based on a 10-degree field of view

Many spectrophotometers can obtain measurements based on both 2-degree and 10-degree fields of view. Here, we performed calibration using a 10-degree field of view, based on the notion that measurements through a 10-degree field of view would more closely reflect the conditions under which monitors are actually used. As Fig. 8 shows, the screens of both monitors subjectively appear to be equally white, indicating that calibrations based on a 10-degree field of view are subjectively more accurate than those based on a 2-degree field of view, which improves white color matching accuracy.

This also confirmed that setting the calibration of measuring instruments to a 10-degree field of view would result in better subjective results.

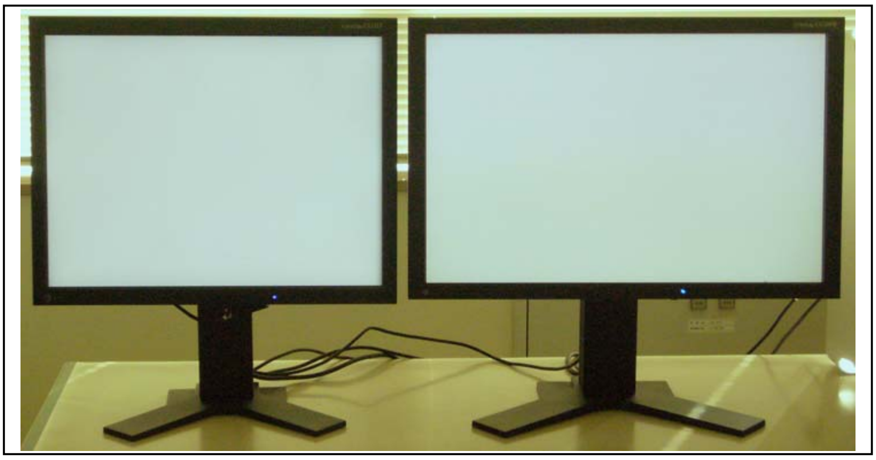


Figure 8: Results of calibration with a 10-degree field of view setting

5. Countermeasures incorporated into ColorNavigator calibration software

Discussed below are various countermeasures incorporated into ColorNavigator, our calibration software, to improve color matching between sRGB and wide gamut (Adobe RGB) monitors.

5-1. White calibration based on a 10-degree field of view

As described in Section 4.1, in ordinary monitor calibration, adjustments and measurement are based on the XYZ values of the XYZ color space based on a 2-degree field of view. In contrast, when the screen colors of two monitors are visually assessed by human observers, colors across a certain screen area are typically observed, as shown in Fig. 5. Thus, actual conditions more closely resemble the conditions of the 10-degree field of view than the 2-degree field of view. CIE (International Commission on Illumination) also recommends the use of the XYZ color space based on a 10-degree field of view for measurements and evaluations of a field of view greater than 4 degrees.

Our ColorNavigator calibration software (Ver. 5.1 and later) features a Multiple Monitor Matching function (see Fig. 9) based on the 10-degree field of view for white calibration. By incorporating the Multiple Monitor Matching function, ColorNavigator improves the accuracy of color matching between sRGB and wide color gamut monitors.*

**ICC profile information is obtained using the 2-degree field of view.*

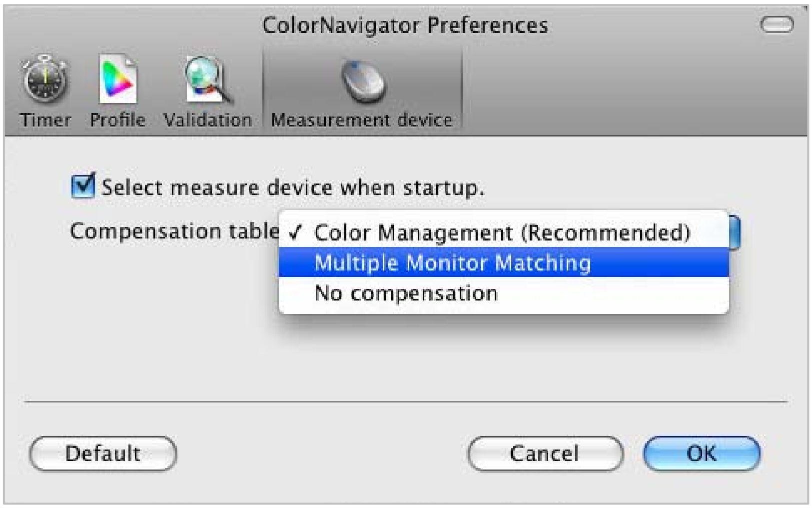


Figure 9

6. Other precautions for color matching between monitors

Color matching for monitors can also be affected by the performance and characteristics of LCD monitors, including differences in contrast ratio, tone characteristics, and uniformity performance. We resolved these problems through the measures described below.

Difference in contrast ratio:

Certain differences in contrast ratio are visible even between two ColorEdge monitors of different LCD modules or types. Contrast performance varies with different LCD modules or types, a factor known to affect color matching of monitors, particularly at low tone levels. In such cases, setting the same target value for the black level in ColorNavigator minimizes the effects of the difference in low tone levels between the two monitors. Since the software's default setting is "minimum value," changing this to the same value for the two monitors reduces the effect.

Differences in tone performance:

Difference in tone performance cannot be user-adjusted. With the ColorEdge series, we adjust the tone for each product at the factory to ensure high quality tone characteristics.

Uniformity performance:

Most ColorEdge series models, including the CG211, CG221, CG301W, CG241W, and CG222W, incorporate Digital Uniformity Compensation circuits to achieve uniform brightness and color on screen.

Manual adjustment function:

To meet the needs of users who demand even more rigorous requirements, ColorNavigator offers manual adjustment functions, including functions for white point, brightness, tone characteristics, and 6-color adjustments, for extremely high precision color matching. These functions help visually optimize color matching.

7. Summary

When color matching with monitors with differing color gamuts, it is important to observe how people compare the images on the monitors and to apply the results of these observations to actual measurements and analyses. We learned that changing the measured field of view of the measuring instrument from the conventional 2-degree field of view to a 10-degree field of view—the latter more closely reflecting actual subjective visual assessments—is an effective approach. To achieve high-precision color matching, our ColorEdge series and the ColorNavigator calibration software use a measurements method based on a 10-degree field of view.